iPad apps that promote mathematical knowledge? *Yes, they exist!*

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Having trouble finding the right app? In this article, Kevin Larkin discusses the difficulties teachers encounter when searching the App Store for high quality, appropriate apps that support students' mathematical learning. Kevin provides a useful link to a collection of over 100 app reviews.

Recently I charged my first-year university students with the task of locating and critiquing a digital resource that could support mathematical learning for primary-school-aged children. iPad apps were a popular initial choice due to the devices being increasingly used in primary schools and the apparent ease of finding an app. However, a search of the iPad store cooled the students' initial enthusiasm as they immediately experienced difficulty in determining which of the thousands of available apps would be suitable. Many practising teachers experience the same difficulty in making an informed decision on the usefulness of apps for primary school mathematics classrooms.

This article presents a brief account of how over 4000 mathematics apps were initially sorted and then critiqued by the author according to criteria that included levels of mathematical knowledge (conceptual, procedural and declarative) and relevance to *Australian Curriculum: Mathematics* content. It needs to be noted that this article is not an endorsement of Apple products. The decision to review Apple applications, rather than Android applications, reflects their market share in school-based use via iPad, iPod and iPhone devices.

By way of background, Pelton and Pelton (2012) noted that:

> ...while some [mathematics application software (Apps)] are commendable, almost all of the rest are simple flashcards, numeric procedures, or mobile textbooks. Very few currently available apps have engaged best practices by integrating visual models to support sense-making (p. 4426).

In an earlier article in APMC, Attard and Northcote (2011) found that there were literally thousands of mathematics-based apps available either free or for a small price, and that the onus was on teachers to test the apps for appropriateness prior to their use in classrooms. This is a difficult task as classroom teachers are 'time poor', thus limiting the likelihood of implementing innovative mathematical approaches (Leong & Chick, 2011) such as the use of iPads to develop student mathematical understanding. Even if teachers had the time to search the plethora of mathematical applications available in the App Store, it is not easy to determine their quality based on information available which largely serves as an 'infomercial' for the software (Shuler, Levine & Ree, 2012). In addition, the available

information is often based on the US *Common Core State Standards (Mathematics)* which are different from those used in the *Australian Curriculum: Mathematics* (ACARA, 2012). Because of the minimal amount of information available, it is likely that teachers are unaware of the availability of quality maths apps.

How the apps were categorised

The categorisation of the apps commenced with a targeted search for mathematics apps in the iTunes App Store. Given that the initial search term "mathematics education" returned 3740 apps (the numbers of apps available on any one day is very fluid as they are added and removed constantly), the search was narrowed.

A targeted search using the term "elementary mathematics" returned 202 apps, "primary mathematics" returned 107 apps, "junior mathematics" returned 20 apps and "infant mathematics" returned 15 apps. Many of the same apps appeared in two or more of the searches. A final list of 142 was selected for full review according to the following conditions:

- only one app in the series was reviewed where there were a number of titles in a series (e.g., *Expert Addition*, *Expert Multiplication*);
- non-English apps (e.g., *iTabuada*) and apps designed for a curriculum from other countries (e.g., Singapore maths apps) were excluded;
- apps that were categorised in the App Store as games, entertainment or lifestyle, or were part of a bigger package of reading, writing and spelling, were excluded;
- apps that either simulated calculators or were databases of mathematical terms (e.g., *Mad Minute Maths HD*) were excluded;
- apps that required additional costs for access or further online registration were excluded.

Once the full review process commenced, a number of problems were experienced with linking to declarative mathematics knowledge (Miller & Hudson, 2007) and to content in the *Australian Curriculum: Mathematics.* This was primarily due to the mismatch between the description of the apps provided by the App Store and the actual experience of using the app. The major mismatches were;

- inconsistently labelled app names (e.g., *Maths Attack* and *Learning Maths Operations* (App Store names) became *Monty's Quest* and *Math Practice* respectively when installed);
- inaccurate descriptions of content (e.g., *Number Cents* made no reference to money);
- inappropriate age-level suggestions that were inconsistent with the *Australian Curriculum: Mathematics* content outcomes (e.g., *Abacus Counting Frame for Pre-school*);
- misleading descriptions which indicated conceptual knowledge development but provided only drill-and-practice-type activities (e.g., *Number Square* which was advertised as encouraging problem-solving but was in fact a 100-square);
- limited to no correlation between cost and quality as a number of the top apps (e.g., *I See Math 1* or *123 Counting Lite*) were free and many of the weaker apps (e.g., *Tillie's Time Shop* or *Math Seeq*) were relatively costly.

It was found that App Store information is not sufficient for teachers to make a valid judgement on whether an app will be useful in developing student mathematical understanding. A scan of a number of mathematics apps at Google Play indicated similar issues with determining the quality of an application for Android devices.

The initial evaluation of each app matched the app to strands and sub-strands of the *Australian Curriculum* and included a list of matching content description codes and appropriate year level match according to the relevant description. Table 1 provides a breakdown of the number of apps according to the relevant strands and sub-strands. (NB: Total app count exceeds 142 as some apps include content from more than one strand or sub-strand and are therefore counted more than once.)

It is apparent from the data provided in Table 1 that the Number and Algebra strand, and more specifically the Number and place value sub-strand, are dominant in terms of content incorporated in the apps. Further examination revealed that 82.9% of the Number and place value apps were dedicated to the four operations. Quality apps supporting the Number and

Table 1. Number of apps with content from Australian Curriculum: Mathematics strands and sub-strands.

Strand	Sub-strand	No. of apps
Number and algebra	Number and place value	105
	Fractions and decimal	10
	Patterns and algebra	7
	Money and financial mathematics	3
	Linear and non-linear relationships	2
	Real numbers	1
Measurement and geometry	Using units of measurement	15
	Shape	12
	Geometric reasoning	4
	Location and transformation	3
	Pythagoras and trigonometry	0
Statistics and probability	Data representation and interpretation	4
	Chance	3

* 87 of the 105 apps dealt only with the four operations. # The Pythagoras and trigonometry sub-strand is only introduced in Australian secondary schools and so was beyond the scope of this review.

Algebra strand include *Find and Count*, *Friends of Ten* and *Column + - * /*. The two dominant sub-strands in Measurement and Geometry were Using units of measurement (60% of these apps dealt solely with time) and Shape (largely Foundation – Year 1 apps focusing on identifying two-dimensional shapes and three-dimensional objects). Quality apps supporting the Measurement and Geometry strand include *Area of Rectangles*, *Time Math Free* and *Solids Elementary HD*.

Whilst there is a paucity of apps incorporating content from the Statistics and Probability strand, one notable worthwhile app for this strand is titled *Statistics!!!* Table 2 provides abbreviated reviews of three of the top apps as an example of the full reviews available at the link provided in the conclusion of this article.

To assist teachers to save time in selecting suitable software, Table 3 indicates a list of the top 40 apps, categorised as Tier One through to Tier Five, based on their relevance to the *Australian Curriculum: Mathematics* and their usefulness in developing mathematical knowledge. Whilst all of these apps are appropriate and relevant for use in primary school classrooms, Tier One are the most useful and should be considered first.

In summary, this article found that the 142 apps reviewed varied greatly in their appropriateness and usefulness. The 142 full app reviews are publicly available via an online spreadsheet located at http://tinyurl.com/ACARA-Apps. These reviews will assist primary school teachers to determine suitable applications that support mathematical understanding and match the *Australian Curriculum* requirements for mathematics. While it is the case that many applications were little more than digital flash cards encouraging rote learning, there were at least 40 worthwhile mathematical apps to support mathematical learning in primary classrooms. What is clear is that assistance in locating useful mathematics applications would be useful for 'time poor' teachers and, therefore, in moving this research forward, it is my intention to work with other mathematics teachers to continue to develop the online spreadsheet as more apps become available for review and classroom use. Please contact the author if you wish to contribute a review of a mathematics app that you have used successfully in your classroom.

Table 2. Sample of three of the 142 app reviews (Tier one apps).

App name	Price	Strand	Sub-strand	Year	Code	Knowledge
Area of Rectangles	$0.99	Measurement and Geometry	Shape Geometric Reasoning	7	ACMMG159 ACMMG165	Conceptual and Procedural
Reviewer comments: There are four components to the app that can be completed in any order. The lesson component is an interactive series of 21 slides with voice and diagrammatic support including the use of manipulatives. Key conceptual development occurs at this stage. The second component is a virtual geoboard where students can draw, and then manipulate, their own rectangle. They can fill the rectangle, change its length and width, and also create rectangles of different size and shape that cover the same area. The third component is a ten-question multiple-choice test. The fourth component is a challenge component. Students are given the opportunity to manipulate various rectangles to assist them in determining the area of various rectangles. They are also required to manipulate the geoboard to create rectangles of various sizes. The challenge component is useful as it generates random questions. Throughout the application drawing tools are available for students to draw their own square units. The application keeps track of the students' progress and can be cleared so that the app can be used more than once by a group of students. A comprehensive help menu is available.						

App name	Price	Strand	Sub-strand	Year	Code	Knowledge
I See! Math1	Free	Number and Algebra	Number and Place Value	F–2	Multiple codes	Conceptual and Procedural
Reviewer comments: Includes single-digit and two-digit numbers, ordinal numbers, addition and subtraction. Students can choose which they do first. Objects are highlighted, and the number spoken, as they are counted. The count is also represented by dots in a tens frame. Zero is also modelled. High-level language is needed, above the level of the mathematics. Overall, too much reading is expected. Knowledge of positional words is needed — the front two, fifth from the front — so knowledge of ordinal numbers is a prerequisite. In the multiple-choice practice mode, students are shown a range of objects which they first have to count before selecting the correct answer. They can keep guessing until they answer the question correctly. Students are asked to match object to symbol, language to symbol and language to object throughout all of the activities. Scaffolding is inconsistent; students are encouraged to try again if the incorrect answer is selected but are not always given direction as to why they might be wrong or clues to answer the question correctly.						

App name	Price	Strand	Sub-strand	Year	Code	Knowledge
Find and Count	$2.99	Number and Algebra	Number and Place Value	2	ACMNA001 ACMNA002 ACMNA289	Conceptual and Procedural
Reviewer comments: The app consists of six different contexts; e.g., a circus and a shopping centre with various objects to count (up to 9) in each context. A voice prompts students to select an object to count. Students then move a bead up to match the object (all objects are displayed at the top of the screen). The bead is then moved from the picture to a counting stick and the number is spoken. At any stage the student can push a button to check whether they have counted all of the selected objects. If the student is correct a congratulation message is spoken; if incorrect an encouraging message is spoken and the student returns to the picture to continue counting. If the student places too many beads on the counting stick, part of the correction is for them to remove beads. Once they have counted the number of objects correctly, it is ticked, the symbol is displayed, and a representation of the symbol is also presented for visual reminder.						

Table 3. Top apps according to relevance to Australian Curriculum: Mathematics and mathematical knowledge.

Tier One	Tier Two	Tier Three	Tier Four	Tier Five
• Area of Rectangles • Common Core Number and Operations in Base Ten (K – 2) • Early Numbers: Maths Wizard Counting • Find and count • I See! Math 1 • Mathemagica – Kids Math • Miracle Learning for Calculation	• 123 Counting Fun • Adding Beads • Friends of Ten • Hands-on Equations • Hands-on Maths • Number Sense • Learn Math 1 (Mondiso) – Add /Subtract • Learn Numbers: Learn2Count • Marble Math Junior • Math Dream • Maths Skill Builders	• Fact Families: addition and subtraction • Fun Count App • Hands-on Maths • Attribute Blocks • Math Galaxy • Fractions Fun • Math Model • Time Math Free • Visual Math 1	• Astromat Base Ten • Number Blocks • Column + – × ÷ • Kindergarten Math • Math Grade One • Middle School Math HD • Patterns, Colors and Shapes • Statistics!!! • Telling Time HD • Toddler Counting 123	• 1st Calc • Geometry for Kids • Abby Adventure Winter Maths • Solids Elementary HD • Adventure Basic School Maths • Letz Learn Counting

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